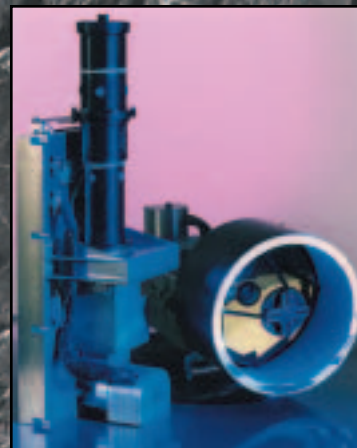
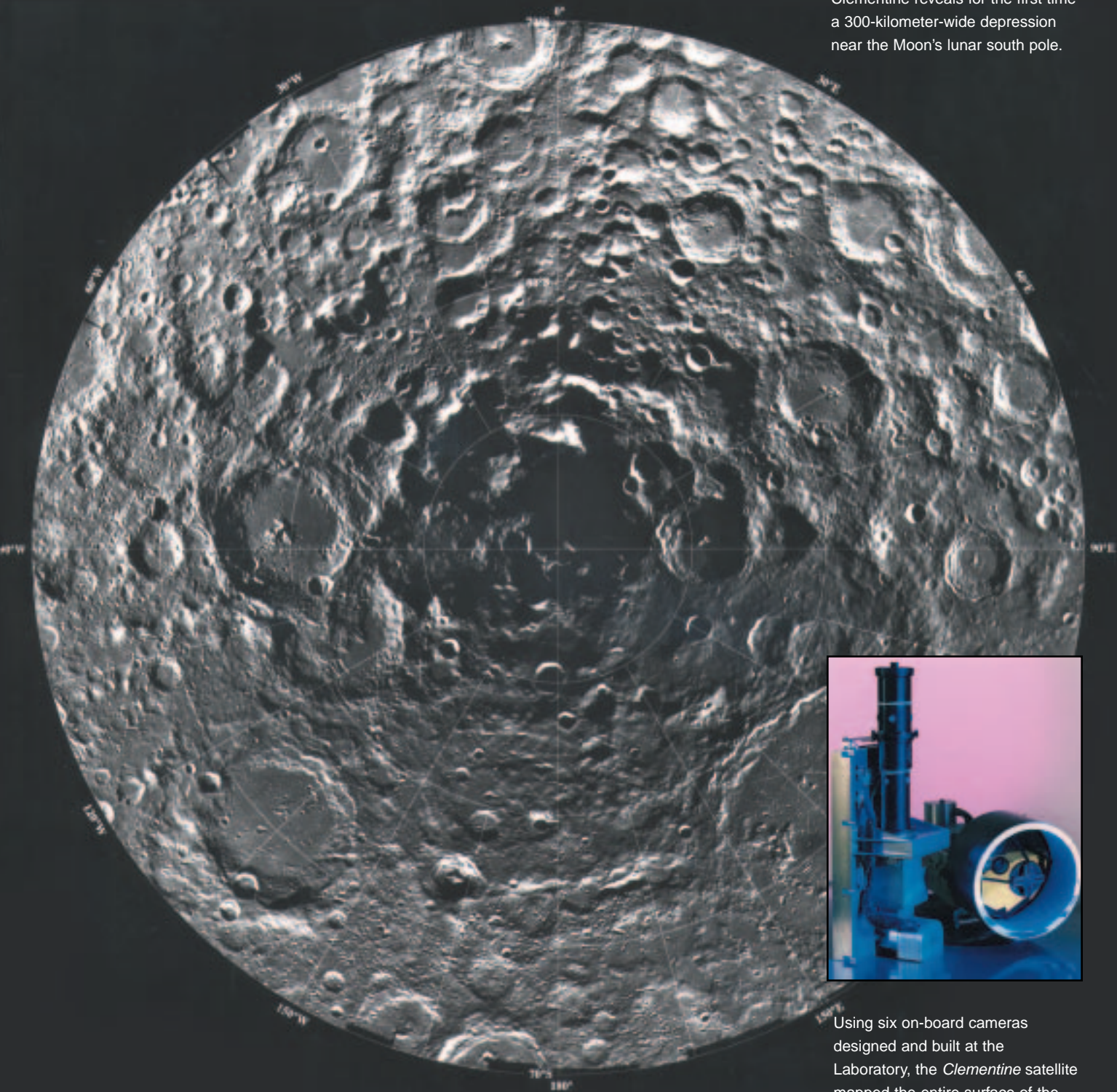


# 1994 CLEMENTINE

A mosaic of 1,500 images taken by Clementine reveals for the first time a 300-kilometer-wide depression near the Moon's lunar south pole.



Using six on-board cameras designed and built at the Laboratory, the *Clementine* satellite mapped the entire surface of the Moon in 1994 at resolutions never before attained.

## Advanced Sensors Map the Moon

The Clementine Deep Space Experiment, sponsored by the Ballistic Missile Defense Organization, was launched on January 25, 1994—22 months after the effort began. At a mission cost of less than \$100 million, it was the first U.S. spacecraft to visit the moon in over two decades. The Clementine mission collected over 1.7 million images during its two months in lunar polar orbit. The data has enabled global mapping of lunar-crust rock types and the first detailed investigation of the geology of the lunar polar regions and the lunar far side.

The *Clementine* spacecraft included new advanced technology sensors and space component technologies that provide the basis for a next generation of lightweight satellites for civilian and military missions. It incorporated 23 advanced subsystem technologies and had a dry mass of only 500 pounds. The spacecraft's payload consisted of an advanced sensor suite weighing less than 16 pounds that was designed, fabricated, integrated, and calibrated by Laboratory scientists and engineers with the support of industrial contractors. The Naval Research Laboratory designed, integrated, and operated the spacecraft. NASA provided mission design and operational support.

*Clementine* carried an ultraviolet-visible camera, a shortwave infrared sensor, a longwave infrared sensor, an imaging lidar (light detection and ranging) instrument, and two Star Tracker cameras. These instruments successfully mapped the entire lunar surface in 11 spectral bands. By laser ranging, the lidar system also generated a global topographical data set. The topography of the moon's many ancient impact basins was measured, and a global map of the thickness of the lunar crust was derived. In addition, bistatic radar measurements made over the Deep South polar depression indicated the presence of frozen water on the moon.

Sensor system technologies were derived from Livermore's space-based interceptor development program. The Strategic Defense Initiative Organization (SDIO) funded related research beginning in 1985, and in November 1987, the Brilliant Pebbles effort formally commenced. The concept was to deploy a constellation of sophisticated, inexpensive, lightweight spacecraft in

low Earth orbit—Brilliant Pebbles—that could detect and hunt down missiles over distances of thousands of kilometers without external aid. In the summer of 1989, Brilliant Pebbles was adopted by SDIO as the new baseline for the space-based segment of a national missile defense system.

A wide variety of projects to develop state-of-the-art sensor technologies at the Laboratory are building on the success of the Clementine program. One example is the development of a large-format digital camera system that uses charge-coupled device detectors. The 16-million-pixel cameras have been used by astronomers in the search for massive compact halo objects (MACHOs), a form of dark matter.

### O Group

Under the leadership of physicist Lowell Wood, O Group pursued a variety of imaginative research projects in the late-1970s and the 1980s. O Group included many extremely talented young scientists, some of who came to the Laboratory as Hertz Foundation fellows. An exceedingly ambitious early project was the design of the S-1 supercomputer, an effort which led to the development of computerized design methods, including Structured Computer-Aided Logic Design (SCALD), that successfully spun-off from the Laboratory. O Group pioneered the development of x-ray lasers and gave birth to the concept of Brilliant Pebbles.



Lowell Wood presented President George Bush with a conceptual model of Brilliant Pebbles when the President visited the Laboratory in 1990.